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Saving the World's Terrestrial Megafauna

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76 **From the late Pleistocene to the Holocene, and now the so called Anthropocene, humans**

77 have been driving an ongoing series of species declines and extinctions (Dirzo et al. 2014).

78 Large-bodied mammals are typically at a higher risk of extinction than smaller ones (Cardillo et

79 al. 2005). However, in some circumstances terrestrial megafauna populations have been able to

80 recover some of their lost numbers due to strong conservation and political commitment, and

81 human cultural changes (Chapron et al. 2014). Indeed many would be in considerably worse

82 predicaments in the absence of conservation action (Hoffmann et al. 2015). Nevertheless, most

83 mammalian megafauna face dramatic range contractions and population declines. In fact, 59% of

84 the world's largest carnivores (≥ 15 kg, $n = 27$) and 60% of the world's largest herbivores (≥ 100

85 kg, $n = 74$) are classified as threatened with extinction on the International Union for the

86 Conservation of Nature (IUCN) Red List (supplemental table S1 and S2). This situation is

87 particularly dire in sub-Saharan Africa and Southeast Asia, home to the greatest diversity of

88 extant megafauna (figure 1). Species at risk of extinction include some of the world's most

89 iconic animals—such as gorillas, rhinos, and big cats (figure 2 top row)—and, unfortunately,

90 they are vanishing just as science is discovering their essential ecological roles (Estes et al.

2011). Here, our objectives are to raise awareness of how these megafauna are imperiled (species in supplemental table S1 and S2) and to stimulate broad interest in developing specific recommendations and concerted action to conserve them.

Megafauna provide a range of distinct ecosystem services through top-down biotic and knock-on abiotic processes (Estes et al. 2011). Many megafauna function as keystone species and ecological engineers, generating strong cascading effects in the ecosystems in which they occur. These species also provide important economic and social services. For example, ecotourism is the fastest growing subsector of tourism in developing countries (UNEP 2013), and megafauna are a major draw for these tourists. Besides contributing considerable revenue to conservation, wildlife-based tourism can contribute significantly to education, economies, job creation, and human livelihoods.

Many of the surviving mammalian megafauna remain beset by long-standing and generally escalating threats of habitat loss, persecution, and exploitation (Ripple et al. 2014, 2015). Large mammals are extremely vulnerable to these threats due to their large area requirements, low densities (particularly for carnivores), and relatively “slow” life history traits (Wallach et al. 2015). Various anthropogenic forces such as deforestation, agricultural expansion, increasing livestock numbers, and other forms of human encroachment have severely degraded critical habitat for megafauna by increased fragmentation or reduced resource availability. Although some species show resilience by adapting to new scenarios under certain conditions (Chapron et al. 2014), livestock production, human population growth and cumulative land use impacts can trigger new conflicts or exacerbate existing ones, leading to additional declines. According to the Food and Agriculture Organization, as of 2014, there were an estimated 3.9 billion ruminant livestock on Earth compared with ~8.5 million individuals of 51 of 74 species of wild

114 megaherbivores for which population estimates are available within their native ranges
115 (supplemental table S2), a magnitude difference of ~400 times.

116 The current depletion of megafauna is also due to overhunting and persecution: shooting,
117 snaring, and poisoning by humans ranging from individuals to governments, as well as by
118 organized criminals and terrorists (Darimont et al. 2015). Megafauna are killed for meat and
119 body parts for traditional medicine and ornaments, or because of actual or perceived threats to
120 humans, their crops or livestock. Meat and body parts are sold locally, to urban markets, or
121 traded regionally and internationally. Striking instances include the slaughter of thousands of
122 megafauna such as African elephants (*Loxodonta africana*) for their ivory, rhinoceroses for their
123 horns, and tigers (*Panthera tigris*) for their body parts. In addition, many lesser-known
124 megafauna species (figure 2, bottom row) are now imperiled (supplemental table S1 and S2).
125 Most of the world's megaherbivores remain poorly studied and this knowledge gap makes
126 conserving them even more difficult (Ripple et al. 2015).

127 Under a business-as-usual scenario, conservation scientists will soon be busy writing obituaries
128 for species and subspecies of megafauna as they vanish from the planet. In fact, this process is
129 already underway: eulogies have been written for Africa's western black rhinoceros (*Diceros*
130 *bicornis longipes*) and the Vietnamese subspecies of the Javan rhinoceros (*Rhinoceros sondaicus*
131 *annamiticus*) (IUCN 2015). Epitaphs will probably soon be needed for scimitar-horned oryx
132 (*Oryx dammah*), now extinct in the wild; the kouprey (*Bos sauveli*), last seen in 1988; and the
133 northern white rhinoceros (*Ceratotherium simum cottoni*), which now numbers three individuals
134 (IUCN 2015). The Sumatran rhino (*Dicerorhinus sumatrensis*) is already extinct in the wild in
135 Malaysia and is very close to extinction in Indonesia with the population collapsing during the
136 last 30 years from over 800 to fewer than 100 (supplemental table 2). The Javan rhino

(*Rhinoceros sondaicus*) is down to a single population of ~58 in a single reserve (supplemental table 2). The Critically Endangered Bactrian camel (*Camelus ferus*) and African wild ass (*Equus africanus*) are not far behind. Even in protected areas, megafauna are increasingly under assault. For example, in West and Central Africa, several large carnivores [including lions (*Panthera leo*), African wild dogs (*Lycaon pictus*), and cheetahs (*Acinonyx jubatus*)] have experienced recent severe range contractions and have declined markedly in many protected areas (IUCN 2015).

Although many of the general causes and mechanisms of declines are well identified and recognized, this understanding has not translated into adequate conservation action. Some of the existing mammal prioritization schemes could be incorporated into a comprehensive global strategy for conserving the largest mammals (Rondinini et al. 2011). Increasing prioritization and political will to conserve megafauna—and actions to restore or reintroduce them in areas where they have declined or been extirpated (such as plans to reintroduce scimitar-horned oryx into Chad and to rehabilitate the entire Gorongosa ecosystem in Mozambique)—are urgently needed. We suggest that the problem has two parts: i) a need to further and more effectively implement, expand, and refine current interventions at relevant scales and; ii) a need for large-scale policy shifts and global increases in funding for conservation to alter the framework and ways in which people interact with wildlife.

In order to save declining species, there is a need to increase global conservation funding by at least an order of magnitude (McCarthy et al. 2012). Without such a transformation, there is a risk that many of the world's most iconic species may not survive to the 22nd Century. We must not go quietly into this impoverished future. Rather, we believe it is our collective responsibility, as scientists who study megafauna, to act to prevent their decline. We therefore present a call to the

broader international community to join together in conserving the remaining terrestrial megafauna (see declaration in Box 1).

From declaration to action

Social and political commitment to provide sufficient protection across the vast landscapes needed for the conservation of the world's megafauna is increasingly required. International frameworks and conventions such as the Convention on Biological Diversity (CBD), the Convention on the Conservation of Migratory Species of Wild Animals (CMS), and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) have had some success in safeguarding species and regions. However, the decisions of these conventions are not always binding, and they will require substantially increased political will and financial support if they are to be effective in the critical task of securing the survival of the world's megafauna. Some regional legal instruments such as the CMS Gorilla Agreement and the Global Tiger Initiative incorporate environmental or biodiversity commitments, and are playing a growing role in protecting biodiversity. International agreements are often well-placed for enforcing regional frameworks for megafauna; examples include the African Elephant Action Plan and the regional conservation strategy for cheetahs and African wild dogs. However, implementation of such initiatives requires financial resources and capacity that are seldom available at those locations where the highest diversity of megafauna remains (figure 1). Therefore, the onus is on developed countries, which have long ago lost most of their megafauna, to not only embark on conservation and restoration programs on their own lands, but also support conservation initiatives in those nations where diverse megafauna still persist. For conservation efforts to be successful, actions should be taken at all levels by authorities that have the public interest in mind, and to work to secure the continued existence of these species.

183 Successfully conserving megafauna requires bold social, political, and financial commitments
184 from nations around the world. Through understanding the value and importance of local human
185 needs, and by combining international financial support with a coordinated multilateral approach
186 to conservation, it may be possible to rescue megafauna from the brink of extinction. As
187 biologists, ecologists and conservation scientists, we are mindful that none of our arguments are
188 new, and that our prescriptions are far easier to write out than to accomplish. However, our
189 objective in presenting them together here is to demonstrate a consensus of opinion amongst the
190 global community of scientists who study and conserve these animals, thereby emphasizing to
191 the wider world the gravity of the problem. Our hope is that this declaration, with the proposed
192 actions and list of signatories, will attract the public and media attention that this issue requires
193 to galvanize opinion, catalyze action, and establish new funding mechanisms. Comprehensive
194 actions to save these iconic wildlife species will help to curb an extinction process that appears to
195 have begun with our ancestors in the late Pleistocene.

197 **Acknowledgements**

198 We thank L. West for work on the estimated population sizes in the appendices.

201 **Supplemental material**

202 **Supplemental table S1:** The 27 large terrestrial carnivores (order Carnivora) with average
203 masses of at least 15 kg. In addition to common and scientific names, average species masses
204 (kg), estimated population sizes (sources: IUCN 2015, Ripple et al. 2014), IUCN Red List threat

category, population trends, and years assessed are shown. Red List categories are: LC (Least Concern), NT (Near Threatened), VU (Vulnerable), EN (Endangered), CR (Critically Endangered). Population trends are: Dec (decreasing), Stable, Inc (increasing), Unk (unknown).

Supplemental table S2: The 74 large terrestrial herbivores with average masses of at least 100 kg. In addition to common and scientific names, average species masses (in kg), estimated population sizes (sources: IUCN 2015, Ripple et al. 2015), IUCN Red List category, population trends, and years assessed are shown. IUCN Red List categories are: LC (Least Concern), NT (Near Threatened), VU (Vulnerable), EN (Endangered), CR (Critically Endangered), EW (Extinct in the Wild). Population trends are: Dec (decreasing), Stable, Inc (increasing), Unk (unknown).

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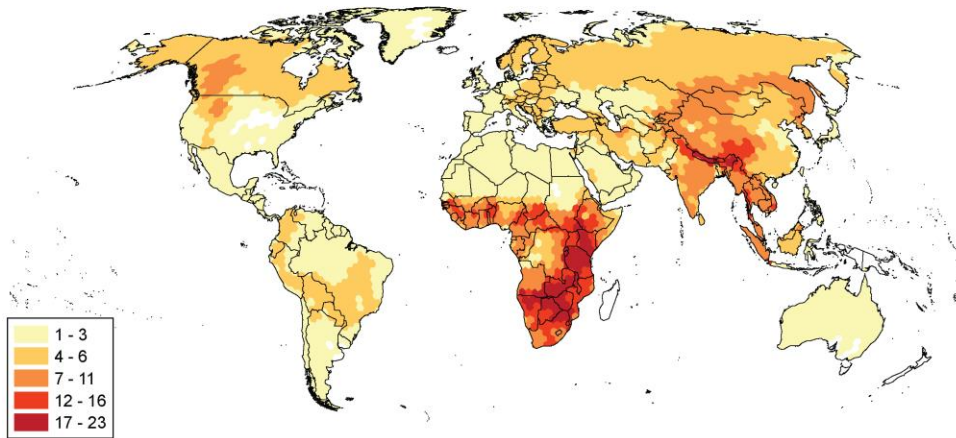
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Figures

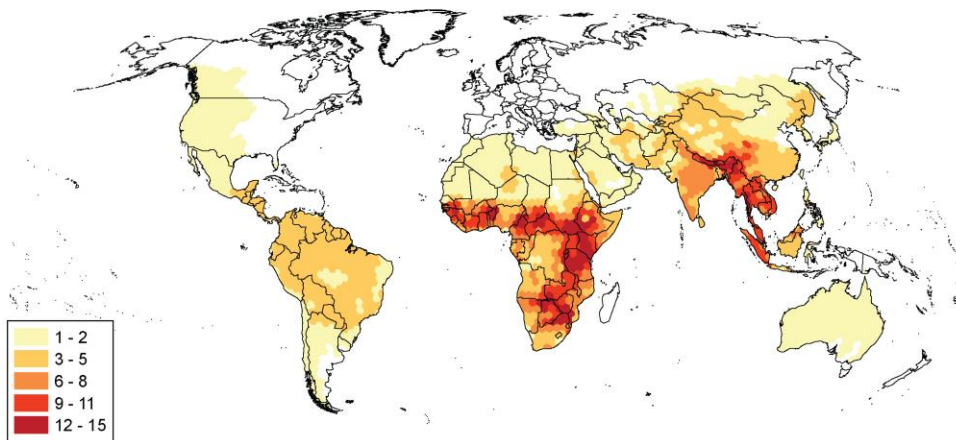
Figure 1. Richness map of (a) number of megafaunal species, (b) number of declining megafauna species, and (c) number of threatened megafaunal species in their native ranges. Megafauna are defined as terrestrial large carnivores (>15 kg) and large herbivores (>100 kg). Threatened includes all species categorized as Vulnerable, Endangered or Critically Endangered on the IUCN Red List (see supplemental tables).

Figure 2. Photos of **well-known species**, top row left to right: Western gorilla (*Gorilla gorilla*) (CR), black rhino (*Diceros bicornis*) (CR), Bengal tiger, (*Panthera tigris tigris*) (EN); and **lesser-known species**, bottom row left to right: African wild ass (*Equus africanus*) (CR), Visayan warty pig (*Sus cebifrons*) (CR), banteng (*Bos javanicus*) (EN). Photo credits: Julio Yeste, Four Oaks, Dave M. Hunt, Mikhail Blajenov, KMW Photography, and Kajornyot.

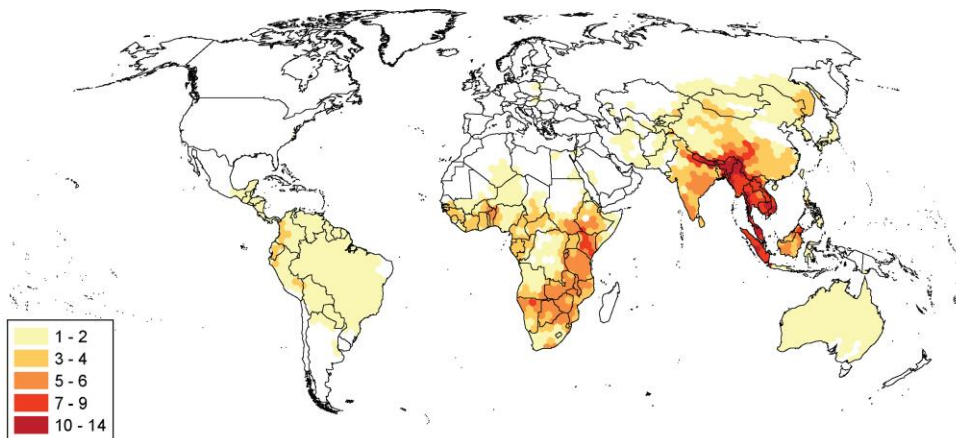
(a) Number of Megafauna



(b) Number of Declining Megafauna



(c) Number of Threatened Megafauna



259

260 **Figure 1.**



Figure 2.

Box 1. A declaration to save the world's terrestrial megafauna.

We conservation scientists:

- 1 Acknowledge that most of the terrestrial megafauna species are threatened with extinction and have declining populations. Some megafauna species that are not globally threatened nonetheless face local extinctions or have critically endangered subspecies.
- 2 Appreciate that 'business as usual' will result in the loss of many of the Earth's most iconic species.
- 3 Understand that megafauna have ecological roles that directly and indirectly affect ecosystem processes and other species throughout the food-web; failure to reverse megafaunal declines will disrupt species interactions with negative consequences for ecosystem function, biological diversity, and the ecological, economic, and social services that these species provide.
- 4 Realize that megafauna are epitomized as a symbol of the wilderness, exemplifying the public's engagement in nature, and that this is a driving force behind efforts to maintain the ecosystem services they can provide.
- 5 Recognize the importance of integrating and better aligning human development and biodiversity conservation needs through engagement and support of local communities in developing countries.
- 6 Propose that funding agencies and scientists increase conservation research efforts in developing countries, where most threatened megafauna occur. Specifically, there is a need to increase the amount of research directed at finding solutions for the conservation of megafauna, especially for lesser-known species.
- 7 Request the help of individuals, governments, corporations, and nongovernmental organizations to stop practices that are harmful to these species and to actively engage in helping to reverse declines in megafauna.
- 8 Strive for increased awareness among the global public of the current megafauna crisis using traditional media as well as social media and other networking approaches.
- 9 Seek a new and comprehensive global commitment and framework for conserving megafauna. The international community should take necessary action to prevent mass extinction of the world's megafauna and other species.
- 10 Urge the development of new funding mechanisms to transfer the current benefits accrued through existence values of megafauna into tangible payments to support research and conservation actions in the places where highly valued megafauna must be preserved.
- 11 Advocate for interdisciplinary scientific interchange between nations to improve social and ecological understanding of the drivers of the decline of megafauna, and to increase capacity for megafauna science and conservation.
- 12 Recommend the reintroduction and rehabilitation of degraded megafauna populations whenever possible, following accepted IUCN guidelines, the ecological and economic importance of which is evidenced by a growing number of success stories, from Yellowstone's wolves (*Canis lupus*), to the Père David's deer (*Elaphurus davidianus*) in China, to various megafauna species of Gorongosa National Park in Mozambique.
- 13 Affirm an abiding moral obligation to protect the earth's megafauna.